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UNDER THE DIRECTION OF THE COMMITTEE OF GENERAL LITERATURE AND EDUCATION APPOINTED BY THE SOCIETY FOR PROMOTING CHRISTIAN KNOWLEDGE.

# ON THE WEATHER.

NIMBUS, OR RAIN-CLOUD; FROM A PAINTING BY TENIERS.

## INTRODUCTION—CHEMICAL AND MECHANICAL CONSTITUTION OF THE ATMOSPHERE.

THE English are reproached for being much influenced by fluctuations in the *weather*, and for perpetually making these the introductory topic in their conversational intercourse; this, as well as all the national peculiarities derived from it, may be accounted for, and even justified; and that which has been made by foreigners the theme for amicable jesting at our expense, may be cited, in friendly retort, as a proof of our physical and moral excellence. The man who resides on an extensive continent, blessed with a tolerably constant climate, is less exposed to those effects on the constitution the native of an island is liable to, the atmosphere of which, from its peculiar situation, is subject to incessant and violent changes; the former, therefore, ought not to reproach the latter for an over-excitability from which he is happily exempted. Both, however, in proportion to their intellectual cultivation, will strive to acquire some knowledge of the general laws governing the atmosphere, essential to their immediate existence, not only as enabling them, in some measure to provide against the evils which might otherwise affect them, but as a rational object of curiosity to thinking and intelligent beings.

The importance of the weather, as governing the supply of our food, has, in all ages, given rise to speculations on its causes and effects, and to anxious endeavours to guard against its influence. The hurricane that lays prostrate his dwelling, the storm that devastates his harvest, the flood that drowns his cattle, the damp that racks his limbs or brings on decrepitude, are always sources of interest to man. In times of ignorance, the feeble in body or mind sought advice from the strong; the knave profited by the credulity of the many, and speculated on future seasons, promising abundance or dearth, health or disease, according to presumptuous guesses, or from interested motives; the dominion which craft obtains over imbecility, has, in this instance, continued down to our own times, but is, happily, yielding to the diffusion of knowledge. The spirit of inquiry, the curiosity that prompts us to investigate the unknown, from worthier motives than the mere supplying of our wants, or the gratification of our sensual pleasures, cannot be directed to a more interesting or difficult subject than that of METEOROLOGY. Our progress in this branch of physical science has happily been commensurate with the importance of the subject, if we are convinced that the causes which combine to regulate the weather are too numerous, and far too complex, to allow of our anticipating, for one moment, the direction in which they will act the next; yet we are equally convinced, that the resulting phenomena are confined within definite limits which they can never surpass; and that however much the *weather* of a country may vary from day to day, the *climate* of that country is constant, or varies insensibly and gradually, from causes not connected with the atmosphere, but which we can indicate and anticipate.

In the progress of a work of such various contents as the *Saturday Magazine*, professing to convey instruction on all innocent and useful topics, many of the subjects connected with what is called the weather have been

already touched on, or even amply elucidated; nevertheless, at the risk of a charge of repetition, we purpose to embody in the present and future Supplement, a concise and connected account of all the phenomena of our atmosphere. In the prosecution of this purpose we shall adopt the following arrangement of our subject; we shall first explain the general principles on which our atmosphere is constituted, we shall then particularize each class of phenomena resulting from this constitution, and subsequently those which result from the additional elements of electricity and light acting in conjunction with the former. Our second great division will consist of an account of the instruments employed in meteorological researches, and, lastly, we shall give a rational collection of precepts, by which a person may form some judgment on the changes about to happen in the weather.

In a popular work, we may be allowed to employ an analogy to illustrate our subject, however much such a practice is to be avoided in more scientific ones. Let us then imagine a highly-organized being, adapted to exist at the bottom of an ocean, liable to constant fluctuations from its mechanical and chemical constitution; it might be expected that such a being would be affected by every such variation in the medium surrounding it. We know, for instance, that if we remove a marine animal into fresh water, or the reverse, disease, and finally death, will ensue; and that evil consequences, of a similar kind, would result from our compelling an animal naturally inhabiting shallow streams to frequent deep and stagnant waters. Man is such an animal, organized to reside at the level bottom of an unfathomable ocean, not less complicated in its constitution, and liable to far greater fluctuations than any experienced by the ocean of water with which we have compared it.

The air which surrounds the globe we inhabit, is an intimate combination of two elementary gases in very unequal proportions, and possessed of the most opposite qualities. *Nitrogen*, which constitutes about four-fifths of the atmosphere, is incombustible, and incapable of supporting the combustion of other bodies, or of supporting life. *Oxygen*, though it cannot be burnt itself, is the principal agent in combustion, and its presence is essential to animal and vegetable existence; these two gases are combined in the same proportions in every part of the atmosphere, as far as we have been yet enabled to ascertain the fact; at the surface of the earth, in the highest regions to which man is enabled to ascend, in the deepest mine, in the most populous city, on the most open plain, atmospheric air is essentially constituted of the same constant proportions of these two principles, and owes its more sensible qualities of clearness or mistiness, of purity or contamination, to the accidental admixture in minute quantities of other matters.

The first, and most important, of these foreign substances is the *vapour* of water, or *steam*, as that element is termed when in the gaseous form. The waters of the globe, exposed to the solar heat, are being continually converted into steam, which is absorbed by the air, till this becomes *saturated*, or fully charged, and can receive no more: the quantity of vapour which the atmosphere can imbibe depends on *temperature* and *volume*. To explain this, if we suppose a given quantity of air, *not* confined, but capable of expanding itself freely as it becomes warmer, then the warmer it becomes, the more steam, or vapour of any kind, it can hold; but if this given quantity of air be confined, so that it cannot expand freely, then there is a certain point of temperature at which it becomes filled with vapour, and can receive no more. If, for example, we were to place a certain quantity of perfectly dry air, and a certain quantity of water in a vessel hermetically sealed, and were gradually to warm the whole, the water would be converted into steam, which would be absorbed or dissolved in the air; but when the air was heated, and consequently expanded to a certain degree, its pressure on the surface of the water would prevent the formation of any more vapour, and none could be received by the air; if we could imagine an additional portion to be formed, it would be instantly reconverted into the liquid form, by the pressure of the elastic mixture of air and vapour.

The atmosphere, like every other material body, is acted on by gravity, or is attracted towards the earth, the upper strata pressing down upon the lower ones, and preventing them from expanding by heat so much as they otherwise would do; there is a certain point, therefore, at which the air, subjected to the superincumbent pressure, becomes nearly saturated with vapour, and all additional quantities are reconverted into water, or, in fact, the waters of the ocean, rivers, &c., are prevented from giving out more vapour by evaporation; this point of complete saturation is never absolutely arrived at in nature, because there is unlimited space for the whole air to expand in; and from the unequal temperature of different portions of the atmosphere, and the unequal degrees in which they are charged with vapour, the overloaded portion can always part with some to that which is comparatively drier. The average proportions in which nitrogen, oxygen, and steam are combined in the air are 775, 210, and 15 respectively, in 1000 parts.

Let us again suppose a certain volume of atmospheric air, charged with the degree of moisture due to its temperature; there are two kinds of action by which this volume may be changed, and its condition altered; if it be compressed *mechanically* into a smaller space, a certain quantity of the vapour it contains will be reconverted into water, *and will become visible and sensible;* if the pressure be continued and increased, the whole aqueous matter may be reduced to the liquid form. When this mechanical pressure is removed, *and the temperature of the mass restored to what it was previous to the mechanical action*, the water again assumes the state of vapour, is reabsorbed by the air, and becomes invisible.

But whenever a body, whether solid, liquid, or gaseous, is compressed, heat is given out; *if this heat be conveyed away by other bodies*, and the pressure be continued, there is no limit to which the condensation of most gaseous bodies can be carried, short of their reassuming the liquid state; but if the evolved heat could be prevented from escaping, or if the temperature be maintained by fresh accessions of caloric, the expansive force of a gaseous body is thereby increased till it counterbalances the pressure, and prevents any further reduction of volume.

Supposing the same volume of air, instead of being mechanically compressed, have its temperature lowered, analogous effects are produced; the bulk is reduced, and a certain portion of the vapour is converted into water again, by parting with the caloric which maintained it in its former state.

The effects of equal additions or diminutions of temperature on dry air, on pure aqueous vapour, and on an atmosphere composed of both combined, vary greatly; and without some correct preliminary notions of the laws governing these bodies under such circumstances, the subject of meteorological phenomena cannot be correctly understood. Atmospheric air preserves its gaseous state at all temperatures and under all pressures; no mechanical force, no cold produced by any chemical means within our power, has been yet found adequate to reduce air to the liquid form; under all ordinary circumstances, when unconfined, and at all temperatures, it exerts an elastic force equivalent to the weight of a column of mercury thirty inches high. At 32° of our thermometric scale, water, as we well know, becomes solid, but in that form, as well as at all degrees of temperature above or below, it gives out an elastic vapour, which at 32° is equal to a column of mercury only two-tenths of an inch in height; while at 212°, if unconfined, save by the weight of the superincumbent atmosphere, water at the surface of the sea becomes a gas, having the same elastic force as the air, or one equivalent to a mercurial column of 30 inches. It is, however, found by experiment, that the variation in the elastic force of vapour follows a different law below and above the temperature of 212°.

The tendency of water to be converted into vapour, and the actual quantity of that vapour in the atmosphere, will increase, as we have said, in proportion to the increase of temperature; at all ordinary temperatures, if the heat increase by equal degrees, (or in an arithmetical ratio,) the elastic force of the vapour will increase in a greater proportion, (or in a geometrical ratio*.) Now, since the quantity of vapour given off into the air depends on that elastic force, that quantity will also increase in the same greater proportion. Let us suppose that the atmosphere consisted of vapour only, then the mean temperature of the equatorial regions being 80°, and that at the poles below 32°, at the surface of the earth, the specific gravity of the vapour at the equator will far exceed that at the poles, a condition exactly the reverse of what takes place in an atmosphere consisting of dry air; in the former, therefore, the currents would set

* These expressions will be understood from the following series:—
1 2 3 4 5 6 7....arithmetical, or having a common *difference*.
2 4 8 16 32 64 128....geometrical...............multiplier.

from the equator towards the poles, instead of from the poles towards the equator, as they really do, as we shall presently see, in our mixed atmosphere.

The temperature of the air decreases regularly, in proportion to the altitude above the surface of the earth, at *about* the rate of one degree of our scale for every hundred yards; the causes of this diminution of heat as we ascend, are principally, the permeability of air to the solar rays, which allows these rays to pass through the upper strata without their absorbing much heat, or receiving much increase of temperature; but the solid earth being warmed by the sun, imparts its heat by conduction to the lower stratum of air immediately in contact with the ground; secondly, the diminished density of the higher regions of the air allows of their absorbing a greater portion of heat into a latent form, or so as not to be perceptible to our senses. When, therefore, the air next the earth, becoming warmed by this proximity, rises from its diminished gravity, as it expands in consequence of the removal of the superincumbent weight, the heat which that pressure caused to be sensible, becomes now latent, or the air feels colder to our senses; and it is important to bear in mind, that a diminution of temperature, or of sensible heat, always results from the sudden expansion of a volume of gas or vapour.

At the equator, where the mean temperature at the level of the sea is about 80°, the temperature, at an altitude of 15,000 feet, is reduced to 32°, *if the air be perfectly dry*. On the contrary, if the atmosphere were one of pure vapour, the temperature at the same height, and under the same conditions, would fall only to 70°, and a similar inequality between the two kinds of atmospheres would be found at all latitudes; we should have to ascend much higher in one of vapour than in one of dry air, in order to meet with the same degree of heat, the temperature at the surface, of course, being everywhere dependent on the latitude. At the same time, the specific gravity of the *vapour* at the level of the sea, would always be greater than that at any altitude above it, consequently, in such an atmosphere, there would be no tendency to any vertical currents.

When air and vapour are mixed, the resulting volume, temperature, &c., are not exactly what might have been expected from those of the constituents; if a cubic foot of air at the temperature of 32°, and with an elastic force equal to 30 inches of mercury, be mixed with the same bulk of vapour at the same temperature, and with a force equivalent to ·2 of an inch; the volume of the mixture is not two cubic feet, but only a minute quantity more than one foot; hence the presence of vapour adds but little to the bulk of the air, and, consequently, hardly diminishes at all its specific gravity; the great aërial currents we shall presently have to describe are, therefore, little modified by the quantity of vapour in the atmosphere. If two portions of vapour, of equal bulk, but of different temperatures, are mingled, or if a portion of vapour be brought into contact with a liquid or solid body at a lower temperature, in either case that of the compound is below what would be requisite to preserve the vapour in that form, and the consequence is that a portion is always converted into water.

It has been mentioned that the rate of decrease of temperature, as we ascend in an atmosphere of vapour, would be much slower than that in an atmosphere of air; and that the quantity of vapour immediately depends on the degree of that temperature; that is, though the quantity may be less, it cannot be greater, than that due to the temperature of the air, when it is exactly at this point the atmosphere is *saturated*. But this point of saturation never can be attained, either at the earth's surface or at any distance from it, in a mixed atmosphere, for the following reason. The increase of temperature downwards in air follows an *arithmetical* ratio; and as it is the air which controls the temperature of the mixed atmosphere, that of the vapour is compelled to conform to the temperature of the air, instead of following the geometrical ratio of increase proper to it as vapour; hence the quantity of vapour becomes *proportionally* less and less as we approach the earth, and more so near the equator than nearer the poles; nevertheless, the absolute quantity of vapour towards the equator is much greater than towards the poles, on account of the far higher degree of evaporation in the warmer than in colder latitudes.

These preliminary observations are principally intended to give the reader an insight into the difficulties that must attend all attempts to investigate the meteorological laws governing an atmosphere of a compound nature, enveloping a globe unequally divided into land and water, unequal in its level, and unequally clothed with vegetation; the temperature of the earth, and consequently of the air resting on it, perpetually varying from its different exposures to solar influence, in its diurnal and annual revolutions, every such variation giving rise to fluctuations in the atmosphere, and causing vertical and horizontal currents in the fluid mass. These currents, again, by bringing portions of the air into new situations, where their degree of temperature and moisture must undergo new changes, are productive of new modifications, every such change also exciting the action and interposition of a more incomprehensible, and far more powerful agency than any yet alluded to—Electricity—an agent which controls and modifies every phenomenon of the physical world, and thus cause and effect re-act on each other, till the mind becomes bewildered in any endeavour to comprehend their inextricable complexity, and arrives at the conclusion, that the only method to obtain any just conceptions on the subject, will be to study each principal cause abstracted from the rest.

### OF ATMOSPHERIC CURRENTS, OR WINDS.

When a portion of the air resting on the earth receives an increase of warmth from it, caused by the solar action, that portion of air becoming specifically lighter, in consequence of the expansion produced by the change of temperature, rises upwards, and a fresh portion flows from the surrounding parts at the same level, to obviate the vacancy that would otherwise be occasioned; this action being the necessary consequence of the laws of equilibrium in a fluid mass. That part of the earth's surface immediately next to, or under, the sun, must be always more warmed than the rest; such an action as we have just alluded to, is consequently being perpetually excited in the atmosphere; but as the earth moves in its orbit, each portion of the zone between the tropics is brought in succession under the sun, and the upward current of air is constantly moving its position accordingly. The place of the air thus heated and ascending, is supplied by a *horizontal* current setting from the poles towards the equator, and following the shifting position of the vertical one.

It must be remembered that the atmosphere revolves with the earth in its *diurnal* motion, the equatorial portion accordingly moves with a velocity of about one thousand miles per hour, this gradually decreasing to the poles, where there is no motion whatever from this cause; when a portion of air, therefore, moves from higher latitudes towards the equator, it takes some time before it can acquire the perpetually increasing velocity due to its change of place. A current setting in that direction will not at first move so fast as the earth it passes over, and the effect of this will be an *apparent* motion in the contrary direction to that of the earth, or from east to west. The combined effect of these causes would be two constant, oblique, currents of air setting equally from the north-east and south-east towards the tropics, supposing the sun were always vertical to the equator.

But as the sun for half the year is to the north, and for the other half to the south of the equator, the vertical current caused by its action not only moves round the earth, but follows this deviating course, and the oblique horizontal currents are modified accordingly. These constant currents are those known by the name of the *trade winds*, but they are not in reality either so constant in their force or direction as the regularity of the causes we have explained would at first lead us to expect*. The principal cause of these deviations is the unequal distribution of land and water in the two hemispheres, which occasions other counteracting currents, as we shall presently explain, when we have still further elucidated the subject in its simplest form.

As the currents from the two hemispheres approach the equator, their friction against the earth, revolving faster than they do, diminishes their apparent easterly direction, and their opposite direction from the north and south mutually destroys them before they arrive at the equator, hence there is no sensible wind from this cause at or near the line, while in the extra-tropical regions, the regular winds arising from the same source are obliterated by the more irregular and violent ones produced in other ways. The trade-winds are consequently felt only within, or near, the tropics north and south.

It is obvious that no constant currents towards the equator from the poles could be maintained, unless there were constant currents in the contrary direction to preserve

* For an interesting anecdote connected with the Trade Winds, see *Saturday Magazine*, Vol. VII., p. 190; and also Vol. IV., p. 6.

the balance*. The air, which, heated at the surface of the earth, rises to the higher regions of the atmosphere within the tropics, flows along again towards the poles at that elevation, gradually subsiding, however, as it cools in its progress, till at length it reaches the earth, which it does with a part of that velocity it possessed at the equator, and greater than that of the earth at the latitude of the contact; the consequence is, that a greater force of wind is felt at the place than the simple current would cause: another effect deserving of mention is, that the action of this mass of air moving more rapidly than the earth, tends to increase, by the impact, the velocity of the earth, and thus balances the tendency to a retardation produced at the equator by friction against a volume of air moving more slowly as coming from the poles.

The westerly and south-westerly winds which prevail in our latitudes are supposed to be principally the result of these counter-currents; their existence in the higher regions of the atmosphere is proved by observation. On the top of the Peak of Teneriffe, a constant westerly wind is experienced, and the ashes of the volcano of St. Vincent's have been carried five hundred miles to the eastward by an upper westerly current, when the trade-wind near the surface of the earth would have taken them in the opposite direction.

We have alluded to the unequal distribution of land and water, as one of the causes modifying the trade-winds; the circumstance of the surface of the earth consisting of land and water combined, is an important source of all the periodical winds in every country. To explain the mode of operation, let us conceive the simple case of an island in the sea, brought directly under the sun by the revolution of the earth; the surface of the ground being heated by the solar action for many hours of the day, heats the air in contact with it, and causes the usual vertical current due to this cause. But the surface of water is never heated to the same degree as land, because each accession of heat is employed in converting the water into vapour, or in the process of evaporation; consequently, the air resting on the sea not being warmed by the contact so much as that over the island, does not ascend, but flows horizontally to supply the deficiency that the upward current would occasion. This wind, which sets from the sea towards land, is called the *sea-breeze*, and is felt near the shore, more especially in tropical countries. After the sun has set, and the supply of heat ceases, the earth radiates its surplus temperature into the air; this becomes, towards morning, comparatively cooler than the air at sea, which is not exposed to so much inequality of temperature at this time of day; accordingly, a current sets from the land towards the sea, till the increasing power of the sun renews the succession of causes which occasion the sea-breeze to be felt in the afternoon.

It may be easily imagined that similar results would be occasioned by differences of soil, of elevation, of vegetable clothing, &c., or by any causes which would produce unequal degrees of surface-temperature over an extensive continent, though the ceaseless fluctuation, and the intervention of those changes due to the quantity of vapour in the air, prevent the partial currents from being so much, or so regularly felt: the great desert of Africa, however, produces a very perceptible and regular periodical wind at sea, well known to traders on the western coast of that continent.

The most remarkable case of deviation from regularity of action, in a constant wind, is presented by the celebrated *monsoons* which prevail only in the Indian Ocean; these winds consist in a regular current, which for six months blows in one direction, and for the other half-year in the contrary. North of the equator, from April to October, a violent *south-west* wind prevails, accompanied with tempests, storms, and rains; a gentle north-east wind and tranquil weather occupy the rest of the season. But both the direction and character of the monsoons vary in different parts of this region of the ocean; the general and striking fact is the existence of a more powerful current setting in the opposite direction to the trade-winds for so long a period. The cause of this monsoon is supposed to be the solar action on the plains of India, Siam, Thibet, &c. These winds are, consequently, *sea-breezes* on a gigantic scale, lasting for months in the year instead of for hours in the day.

The partial winds felt in all countries and at all seasons, which, from the variety in their direction and force, modify the constant currents before alluded to, sometimes obliterating them and sometimes acting in conjunction, and thereby increasing their power, are occasioned by the ever-varying and unequally-distributed quantities of vapour contained in the air. When a mass of air nearly saturated with vapour is suddenly altered in volume, either by the condensation of this, and by the consequent change in temperature, or by some electric change, the equilibrium is restored by a current from some other part, where the opposite conditions prevail. But it would be futile, in this place, to endeavour to enter into any explanation of the series of actions that produce these winds. The reader, from what has preceded, will comprehend the general nature of the question, and for further information must refer to scientific works on meteorology. If it should seem to him that the causes alluded to do not appear adequate to the production of those tremendous storms which bring ruin on all the fabrics of man's hands, he must revert to the real relation between the physical agency and the being who suffers. The main body of the atmosphere, like the ocean of water, is but a thin coating to the vast bulk of the globe†; the local disturbances in this envelope commonly extend for an inappreciable distance on the surface. A hurricane may devastate an island in the West Indies, while the most perfect calm exists on one not fifty miles from it, and we know that a storm of wind may unroof houses and tear up trees, in a county of our own island, the existence of which is only first known to an adjoining one by the accounts of the damage sustained.

The power of wind, of course, depends on the velocity of the current of air, and this may vary from no motion at all, to a rate of upwards of one hundred miles per hour, which is commonly supposed to be that at which the wind moves in what is called a hurricane. Instruments have been contrived for measuring the force and velocity of wind, and hence called *anemometers;* in these a given, constant, surface is exposed to be acted on by the current of air, and the relative mechanical effects produced on a connected part of the machine, are indicated by a graduated scale. By these contrivances, a kind of table of the velocity and force of winds has been formed; from this, it appears, that when the air moves at the rate of a mile in an hour, or one and a half feet in a second, its force on a foot square of surface is equivalent to a weight on that surface of ·005 of a pound, and its existence is hardly perceptible. When it moves ten miles per hour, the force on the square foot is about half a pound, and constitutes a pleasant gale. A *high wind* moves from thirty to thirty-five miles per hour, and exerts a force of from four and a half to six pounds. A storm or tempest moves fifty or sixty miles, with a force of from twelve to seventeen pounds; and when the wind moves 100 miles per hour, and exerts a force of 50 lbs on a square foot, it becomes a destructive hurricane. The experiments are, however, uncertain, and the terms deduced from them vague in the extreme; the question is only one of curiosity, and for reasons which need not be detailed, incapable of accurate solution.

### LOCAL WINDS.

It is quite possible that a periodical wind, which in its course passes over a tract of marshy country, may bear along with it some gaseous foreign matters, which may render that wind noxious. Thus the simoom *is said* to carry nitrous gas, the harmattan, oxygen in excess, and the khamsin an excess of azote along with them. It is probable that these effects have been greatly exaggerated, and a sufficient number of experiments have not been made even to substantiate the fact. If a wind blow over a dry

* The existence of currents of air setting in different directions at different altitudes, at the same time, is proved by the motions of clouds, which are often seen to move in a contrary direction to that in which the wind is blowing at the surface of the earth. Aëronauts, in ascending in balloons, find several currents simultaneously blowing from different points of the compass; and they frequently avail themselves of these to avoid being carried out to sea, or, as far as they are able, to steer their machine in the direction they wish to go.

† The atmosphere is supposed to extend to a height of 45 miles above the surface of the earth; but from the rapidly diminishing rate of its density, by far the greater portion of the air is comprised in a stratum not extending to more than 15 or 20 miles in height. The centrifugal force, arising from the diurnal rotation of the earth, must occasion the atmosphere to assume a form much more spheroidal than that of the solid globe; that is, the height of the atmosphere will be much greater at the equator than at the poles, and the solar action will contribute to increase this inequality. It is a remarkable fact, that scientific men are not agreed as to the extent of the atmosphere, and the question even involves the consideration of the finite, or infinite, divisibility of matter.

and burning tract of sand it is deprived of the greater part of that moisture which is requisite to render it beneficially respirable by man and animals, and the effects of such a wind are sufficiently distressing, more especially if it bear along with it fine sand, which will irritate and inflame the eyes and throats of those inhaling the air. This seems to be the extent to which the khamsin, harmattan, and other winds coming from over the Sahara are noxious, and it *is not proved* that they really possess any foreign admixture that renders them so.

The *harmattan** is an easterly wind which blows occasionally over Guinea during the months of December, January and February, and is felt along the coast from Cape Verd to Cape Lopez. There is no fixed time of day for its first appearance, and its duration varies from one to fifteen or sixteen days. It is always accompanied by a fog or haze, which occasions a considerable obscurity, and conceals the sun, except when near the meridian, and then it appears of a dull-red colour. The peculiar characteristic of this wind is, however, its extreme dryness, which renders it fatal to vegetation, and produces disagreeable effects on the human body, causing a pricking sensation on the skin, and inducing the necessity for drinking repeatedly, not so much from any feeling of thirst, as to moisten the mouth and palate. If the harmattan continue four or five days, the skin peels off from the hands and face, and finally from the whole body. Wooden articles shrink and crack, and other inconveniences are felt from its protracted stay; yet it is considered beneficial to health, and seems to arrest the progress of contagion.

The simoom, khamsin, and samiel, have been described by different travellers in Africa, and Egypt in particular,—their accounts of its effects varying according as the imaginative faculty of the writer prevailed over his sound sense or scientific acquirements. The story of the simoom is one among a thousand proofs of the effects of knowledge in eradicating superstitions and prejudices, which are the creations of ignorance. It was formerly asserted that the simoom was instantly fatal to any one overtaken by it, and that the source of its destructive qualities was unknown, since none had ever escaped to narrate their sensations, or the appearances accompanying this wind. Bruce, who possessed considerable knowledge and sagacity, so far corrected this error as to survive a simoom to which he was exposed, and to give a more rational account of its effects; but his ardent imagination induced him to exaggerate them greatly, and caused him to attribute a peculiar lurid purple hue to the coming breeze, which subsequent, more prosaic, travellers have not observed.

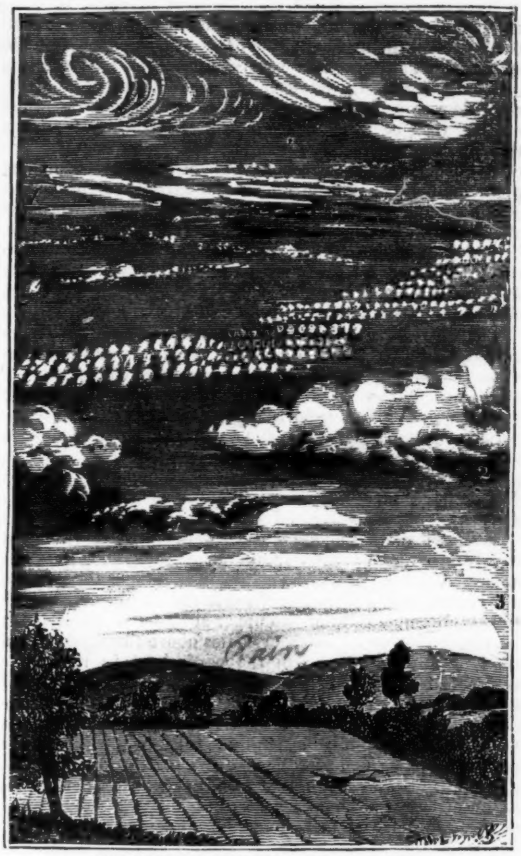
Burckhardt has given the best and most probable account of the simoom, and states that, during its prevalence, the atmosphere is rendered of a reddish or yellowish tinge, by being loaded with particles of fine sand. He describes the pain and inconvenience felt from this cause as great, and that to avoid it the Arabs kneel down to the leeward of their camels for shelter; that those animals are often irritated by this sand being blown into their large and prominent eyes, and will break away from their leaders and seek some bush or rock against which they may shelter their heads; but this intelligent and indefatigable traveller not only often experienced the simoom himself, but made particular inquiries of the Arabs concerning it, and distinctly states that the result was in his mind a conviction that the wind in question never was fatal, or even more than temporarily inconvenient to man or beast; and that the heat during the continuance, though oppressive, was not greater than may be experienced on many other occasions in that country.

"The most disagreeable effect on man is that it stops perspiration, dries and parches the mouth, and produces restlessness; and the greatest evil to be anticipated from it is the evaporation of the water from the skins, effects which might be expected from the nature of the wind."

The *scirocco* of Italy appears to be the simoom modified by its passage over the Mediterranean. According to our countryman Brydone, the heat is oppressive during its continuance, causing great relaxation, but productive of no permanent bad effects.

We shall notice the hurricane, tornado, water-spout, &c., in a subsequent paper, when we come to treat of those atmospheric phenomena in which electric agency is more directly evident.

* Supposed to be a corruption of a native (Fantee) word, signifying a *cold dry wind*.




THE PRINCIPAL MODIFICATIONS OF CLOUDS.

## OF VAPOUR, DEW, MISTS, FOGS, CLOUDS.

THE *vapour* of water, or *steam*, is invisible, and the air saturated or charged with it loses nothing of its transparency; but any diminution of temperature or volume which produces a condensation, however trifling, in the vapour diffused in the air, renders this visible, the vapour reassuming the liquid state of water. The great variety of form and appearance put on by the partially-condensed vapour, arises from the comparative magnitude of the drops into which the liquid coalesces on this change taking place; while these are extremely minute, the drops are buoyed in the air, and the vapour assumes the form of *mist*, *fog*, or *clouds*, according to its quantity, density, and its height above the ground; when the drops are too large and too heavy to float in the air, the water becomes more perceptible in the form of *dew*, *rain*, &c., which, if congealed by a still further reduction of temperature, constitutes, according to circumstances, *hoar-frost*, *snow*, *sleet*, and *hail*.

DEW.—The tendency to an equal distribution of the principle of heat, or *caloric*, among all bodies, in proportion to their *capacity* for it, causes one, which has by any means acquired a greater proportion than is natural to it, to part with that surplus to all others near it. If two solid bodies are in contact, and one be heated more than the other, the first parts with some portion to that other, till both become of an equal degree of temperature to our senses; this process is called *conduction*. When an isolated heated body is placed in a vacuum, or in air, it gives off its surplus heat to space by what is called *radiation:* and here it may be mentioned that air and water are very bad *conductors* of heat in the mode just mentioned, by which heat is propagated through solid bodies; heat is propagated through air and water by another process, called *convection*, already described; that is, by the ascent of a heated portion into the upper strata, causing the cooler portions to descend by their relative gravity, the whole mass becoming of an equal temperature by the repetition of this process throughout it.

Conduction and radiation are, in fact, but modifications of one mode of action, and convection is characterized merely by the motion among the mass consequent on its state of fluidity; the degree of conducting and radiating

powers in bodies is found to be greatly modified by their nature and by their kind of surface. Metals, as is well known, conduct heat better than all other bodies, but the same metal will radiate very differently when it has a polished or a rough surface; a vessel of burnished silver will not radiate half so much heat in a given time as when its surface is tarnished or scratched, or covered over with a coating of lamp-black.

All bodies on the earth impart or receive the surplus heat from one another or from the earth; but the surface of the ground when it has been heated by the sun during the day, radiates its heat into the space above during the night, and becoming thereby cooler than the stratum of air in contact with it, causes a condensation of some of the vapour contained by that air. It is this condensed vapour which constitutes DEW. Dew does not fall from the sky, nor rise from the ground, as it is asserted to do by those who are ignorant of physical science; it is deposited from the air charged with vapour on all bodies in contact with it, according to the different degrees in which those bodies radiate their caloric, and thereby reduce their temperature below the point requisite to keep the vapour of the air, in which they are immersed, in the gaseous form.

The herbaceous matter of vegetables generally radiates heat better than the mineral substances of the earth; this is the reason why grass and plants are always first covered with dew*; and all bodies will become damp when exposed to the air, in proportion to their radiating powers. The reason why more dew is deposited on the upper than on the under surfaces of bodies suspended in the air is, that the diminution of temperature of the upper surfaces is not retarded by any counter-radiation from bodies above them, while, the under surfaces receive from the earth heat in return for that they radiate towards it. If the body be an indifferent conductor, the inequality of temperature between the upper and under surface will allow of the former condensing the vapour of the air, or of becoming dewed, while the under surface remains quite dry; but a plate of metal suspended horizontally above the ground will be dewed on both sides because the metal being a good conductor, the temperature of the two surfaces is kept equal. The non-formation of dew on cloudy nights is thus accounted for: every one who is observant must have noticed how much warmer it feels when the sky becomes overcast after a clear sharp night,—the clouds are a reservoir of heat, and by the gradual condensation of the vapour of which they are formed, are in the state to give out the latent heat of that vapour; hence they radiate to the earth and arrest the depression of the temperature of its surface, and consequently prevent the formation of dew†.

It is clear that the nearer the air is to the point of saturation, the more readily, and in the greater quantity, will dew be formed; the air becomes most loaded with vapour in those situations and times when evaporation is the greatest; this is the reason why dew is more abundant in warm than in cold weather; and if little is deposited in sultry weather it is because the earth is so much heated during the long day, that it has not time to radiate off sufficient heat in the few hours of the sun's absence. In Spring and Autumn, these causes do not operate, and dew is most plentiful towards the end and commencement of these seasons, and from the same cause dew is more abundant in temperate than in tropical countries, and generally after rainy than after dry weather.

Wind prevents the formation of dew, by evaporating it faster than it can be deposited; but a gentle motion of the air is favourable to the deposition of dew by bringing fresh portions of saturated air in contact with the same portion of ground.

The *hoar*, or *rime*, is dew congealed by a still further reduction of temperature, and is accordingly observed under the same circumstances and at the same seasons. The hoar-frosts of Winter are generally subsequent to a period of mild close weather, favourable to evaporation, and as the formation of dew indicates an atmosphere surcharged with vapour, the rain that generally follows a white frost in the morning is partly accounted for. We shall have some further observations to make on frozen dew when we come to consider the analogous formation of snow. In the accompanying engraving are represented some of the beautiful forms assumed by the crystals of frozen vapour, and to these we shall have again to refer.

* The influence of radiation, in producing cold at the earth's surface, would scarcely be believed by inattentive observers. Often, on a calm night, the temperature of a grass-plot is 10 or 15 degrees less than that of the air a few feet above it. Hence, as Mr. Daniell has remarked, vegetables in our climate are, during ten months in the year, liable to be exposed at night to a freezing temperature, and even in July and August to a temperature only two or three degrees warmer.—Dr. PROUT'S *Bridgewater Treatise*, p. 311.

† A delicate thermometer placed on the ground will be affected by the passage of a single cloud across a clear sky; and if a succession of clouds pass over, with intervals of clear sky between them, such an instrument has been observed to fluctuate accordingly, rising with each passing mass of vapour, and falling again when the radiation becomes unrestrained.

### MISTS.

THE immediate cause of MISTS and FOGS, on many occasions, is not accurately known; the atmosphere may at one time be saturated, as is proved by the copious deposition of dew, and yet remain quite clear; at another, and under circumstances apparently similar, a mist will be seen on the earth towards sunset or sunrise: but that there is direct connexion between the two kinds of phenomena is evinced by this fact, that mists and fogs are formed in those places, countries, and seasons, at which dew is most abundant, or where evaporation is the greatest, as over valleys, lakes, rivers, ponds, &c., and during the autumnal months when the sky is clear. At these seasons, the radiation from the land and from the water is most unequal, the difference being the greatest when the temperature of the latter is about 40°, the point when its density is the greatest. At this point the temperature of the water is nearly the same both night and day‡, while that of the land varies considerably, being much above 40° during the time the sun is above the horizon, and below that degree during the night: now, since the body of water must occupy the lower level, the cold air from above the land subsides, and mingling with the warmer mass resting on the water, condenses some of the vapour, and occasions the formation of a mist. When the mist extends to a greater height in the air, and is less confined in its locality, it becomes a fog, the production of which, at a distance from bodies of water, is due to analogous causes.

Cities, like London, having a river running through them, are obnoxious to thick fogs at peculiar seasons; the fires in the houses, and the mass of inhabitants, keep the air at a higher temperature than that of the surrounding country; the atmosphere is supplied with superabundance of vapour, which becomes sensible, by partial condensation, on the occurrence of any cause which lowers the temperature. That the thick fogs of our capital are such partial condensations of vapour, supplied by the Thames, is shown by the fact that they ever begin and remain the thickest in the lowest parts of the town next the river, the dusky hue of our peculiar fogs is occasioned by the dense cloud of coal-smoke constantly hovering over the city.

Mists act like clouds in preventing further radiation, and thus mitigate the cold; they are hence beneficial to vegetation in the low grounds, where mists mostly prevail, as well as by preventing the sudden influx of colder air from the surrounding high land.

The fogs that prevail in seas in high latitudes are all explicable from the same causes. The air, when cooled by the masses of ice, is carried by currents over the ocean towards the equator, where it meets with a saturated and warmer air, and occasions a fog. The gulf-stream, by carrying a mass of warmer water to the neighbourhood of Nova Scotia and Newfoundland, is the cause of the dense fogs that prevail in those seas when the atmospheric currents bring the cold air from the regions of the Polar Sea.

There are, however, some peculiarities in mists that are not yet satisfactorily accounted for, by supposing them to be the result of atmospheric causes solely. There are *dry mists*, *moist mists*, and *mixed*. The first are often characterized by a perceptible odour and colour. In Belgium, dry and fetid mists occur during easterly winds, and mists simply odorous during northerly. They are most frequent in Spring and Autumn, and are very local, thus far agreeing with the usual mists we have already described; but the origin and source of the dry and odorous mist is not known. They also occur in our own country, of a blueish tinge; yellow and light-red mists have been observed by meteorologists of the first rank in Britain, and seamen are made aware of their approach to Malta, at certain seasons, by a peculiar colour in the atmosphere.

‡ Since the density of water at forty degrees is at a maximum, the moment that at the surface cools down by radiation to this point, that stratum sinks and is replaced by another from below which is at a higher temperature; hence, till the whole mass is equally cooled, no part of it can fall below that point.

## CLOUDS.

Clouds are only mists in the upper regions of the air, but they differ from mists in the mode of their formation; when a volume of warm air, loaded with vapour, is carried upwards, it ascends till it arrives at the stratum of the atmosphere, possessing the same specific gravity, allowing for the change it undergoes in this respect by its gradual expansion, as it is more and more freed from the load of superincumbent air. Whether the conversion of the vapour contained by the ascending air into visible mist or cloud be the result of the cold produced by this expansion, or by its coming in contact with a current of colder air, or by the ascending air blending with some above in a different state of saturation, or whether the effect is principally an electric phenomenon, is by no means well ascertained; most probably all these causes commonly combine to produce the effect, and not any one singly.

Clouds have attracted attention at all times, not only from their intimate relation to the subject of weather, and from their consequent influence on our moral and physical being; but because they are among the most beautiful of objects, heightening and varying the charms of every landscape.

Clouds have been classed under three different forms, and of these there are four modifications. They are represented in the accompanying engraving to which we refer in the following enumeration and description.

1. The *cirrus*, or *curl-cloud*, is the name given to the light fleecy clouds that first form in a clear sky; they are elongated in fibrous lines, either curved, parallel, or diverging, and convey the impression of being produced in, or being subjected to, a brisk current of air. The cirrus appears to be formed at the greatest altitude clouds attain; it seldom moves much, and though it changes its form greatly, it will yet give a character to the sky for many hours together. It has been asserted by persons who have made this branch of meteorological phenomena the object of their study, that the presence of cirrus indicates a high state of electrical action in the atmosphere, and that this species of cloud is the immediate agent in electrical currents. At any events, cirri indicate the existence of atmospheric currents, and usually precede the rise or change of wind, and are also frequently soon followed by rain. The curved variety of cirrus is that popularly called *mare's-tail.*

2. The *cumulus*, or *stacken-cloud*, is composed of dense roundish masses, piled up in a pyramidal form; it is the cloud that is seen in the horizon towards evening or at sunset, when it presents those beautiful tints at its edges which cause such pleasure to the lover of nature. The cumulus is generally formed at a lower altitude than the cirrus, and always appears before wet weather, though, perhaps, not immediately. In fine warm Summer days the roundish detached masses of light clouds that occupy the greatest part of the sky appear to be a modification of this kind of cloud. The formation of large cumuli to leeward during a strong wind indicates the approach of calm with rain. In warm sultry weather, when the cumuli near the horizon do not disappear about sunset, but continue to rise, thunder may be expected.

3. The *stratus*, or *fall-cloud*, is the name of all clouds that are not to be ranked under the foregoing; it is the lowest cloud formed in the air, and comprises the mists and fogs we have before described. It is, accordingly, always seen near the horizon, where it presents itself as a cloud, undefined in its outline,—melting into the blue sky at its upper part, and often extending all round the horizon, appearances that are the result of the spectator himself often being in the mist constituting the cloud in question. When the sun rises in a bed of stratus the day is generally calm and fine; it is, however, essentially a night-cloud, and usually passes into the cumulus, or disappears with the return of day.

The three distinct kinds of clouds just enumerated are seldom seen to exist alone or for any continuous time, in temperate and changeable climates; and, as might be expected, in an endeavour to classify or describe so fleeting and changeable a thing as a cloud, the limits between the kinds are not very definable; there are certain modifications of the three clouds we have described, which, partaking decidedly of the character of two of them combined at once, have received names accordingly.

4. The *cirro-cumulus*, or *sonder-cloud;* and *cirro-stratus*, or *wane-cloud*, are well known, and easily recognised in that peculiar regular formation popularly named *mackarel-backed.* Each arises from the regu.ar separation into detached roundish or fibrous masses of a long continuous cirrus, and are most probably an electric phenomenon. They characterize a period of fluctuation in the weather, and especially of wind, but do not immediately precede rain, any more than the cirrus which gives them birth. The resemblance of the first to a flock of sheep has occurred to many, probably from a confused association in the mind of a *fleecy* appearance. The Germans, in their fertile and expressive language, call this cloud *God's lambs*, and the image is beautifully expressed in the following lines:

> For yet above these wafted clouds are seen,
> In a remoter sky still more serene,
> Others detached in ranges through the air,
> Spotless as snow, and countless as they're fair,
> Scattered immensely wide from East to West,
> The beauteous semblance of a flock at rest.
>
> BLOOMFIELD.

5. The *cumulo-stratus*, or *twain-cloud*, as its name implies, possesses a combination of the characters of the cumulus with the stratus, and its derivatives; it constitutes the intermediate state before the increasing mass of condensed vapour becomes so heavy as to fall in rain. The cumulo-stratus is the cloud of most common occurrence in our variable climate, both in fine and changeable weather. It is the essential component of those aërial chains of mountains which, gilt on their edges and summits by the sun setting in the opposite point of the heavens, form so attractive an object for the artist, the poet, or the true philosopher, each, yielding the reins to his imagination, pictures these barriers as dividing him from those realms where "the wicked cease from troubling, and the weary are at rest."

A cloud from which rain is actua.ly descending is called a *cumulo-cirro-stratus*, or *nimbus;* or *rain-cloud;* but it is only during a temporary shower, or during a thunder-storm, that the nimbus can be said to have a definite form, in which its composite nature may be observed; when steady rain for many hours prevails, the whole sky is covered with one unbroken stratus, against which various floating masses of cumulus are observable, these often breaking up into the other principal kinds.

Any of the foregoing modifications of clouds may increase so much as to cover the whole visible expanse of sky; and two or more, at different elevations, may do so conjointly; but it is found from observation, that no cloud deposits rain till it has undergone a change sufficiently remarkable to entitle it to be considered a distinct modification to which the term nimbus has been given. This alteration is the result of the gradual combination into larger drops of the detached smaller vesicles of water which usually constitute clouds. This aggregation is attended with an optical change more easy to recognise than to describe, which we shall have to refer to when we treat of the agency of light in the atmosphere, and the resulting phenomena.

It is very difficult to decide on the altitude of a cloud as seen from the ground, because whatever may be the apparent angle of elevation, unless the distance of the mass be known, we possess no data for forming a judgment. It is obvious that a cloud may appear to touch the horizon that is in reality floating in the highest regions of the air. Of two isolated clouds it is impossible to say, at sight, which is the highest; that which is more nearly vertical to you will of course be seen, as it were, above the other, or as having a greater angle of elevation, and yet it may in truth be at a lower level, as is sometimes proved by its passing between you and the other cloud, or, as it would improperly be called, *over* it*.

Again, two masses of cloud may appear to meet and to combine, when, in fact, one is only interposed between us and the other, and they are really at considerable distances apart. This deception may be rectified in the mind by observing whether the two clouds, as they approach and at last mutually conceal each other, preserve their individual forms. Thus, if a portion of cirrus *appear* to join a cumulus, and we see the former preserve its form, so that its extremities are seen beyond the outline of the latter, we may conclude that there is no real union. But if, as they approach, each cloud begins to change its shape and becomes indistinct and diffuse at its outline, and if, when they appear to unite, the resulting mass is unlike the form either had previously,

* By the same incorrect use of language, a cloud is said to pass *over* the sun or moon. Correctly, we should say, *between* us and the luminary; or, concisely, if not quite properly, *under* the sun or moon.

then we may infer that a real junction of two clouds floating on the same level has taken place.

The form and motion of clouds is thus very deceptive from the effects of *perspective;* a series of parallel cirri will always appear to converge if one end of them be nearer the spectator than the other. Every one must have remarked the radiating appearance of the sun's rays as they break through the clouds of a stormy sky, and yet we know these rays are really parallel lines; for rays of light only become visible in passing through our atmosphere, and all such as arrive within it from the sun are absolutely parallel; the same source of deception affects parallel lines of cirri. A small cloud is frequently seen to rise from *behind* the horizon, to *ascend*, and to grow larger and larger till it spreads over a great portion of the sky; it then is seen to diminish again, to *descend*, and finally to disappear behind the point of the horizon nearly opposite to that where it was first perceived. Now all these appearances are a series of deceptions produced by the motion of a cloud of precisely the same size, passing in a straight line at one altitude above the earth, for such a distance as places it beyond the limits of our visible horizon. When a cloud appears to increase in size without much altering its general form, we may generally infer that it is only an *apparent* change of magnitude produced by the diminishing distance of a cloud as it moves towards and over us. If, however, the form is changing momentarily, it is possibly occasioned by fresh accessions of condensed vapour, which are really increasing the magnitude of the mass.

Since, from the simplest hydrostatic principles, the air possessing different degrees of elasticity, density, &c., must arrange itself accordingly in concentric layers, the clouds, generally speaking, must conform also to this arrangement, or must form horizontal beds at different altitudes; for if we could suppose a mass of homogeneous vapour extending vertically to such a height as to lie in strata of air of decidedly different density, elasticity, &c., it is clear the vapour would be modified at the different levels where these changes took place, and the resulting clouds would assume a different character, or would separate. It is hence certain that the pyramidal or conical form of masses of cumuli, &c., are rather the result of the different angles and direction in which the boundary of a horizontal bed of cloud is viewed from beneath, than the effect of real inequality, to any considerable extent, in the thickness of that bed, though it cannot be supposed that the upper and under surface of a bed of vapour are ever either perfectly parallel or level.

An attentive observer may rightly interpret the apparent positions, motions, and forms of clouds by noticing those of the shadows of each as they glide over the distant fields, and also by observing the manner in which the edges are gilt or coloured by the sun, as well as the effect of rays breaking through a mass of cloud, and this is an exercise that will be found both instructive and amusing, as are all observations of natural appearances.

From the principles we have laid down on the properties of a mixed atmosphere of air and vapour, "it appears that clouds, in general, must be formed at that elevation in the atmosphere in which the mean temperature in the air becomes equal to, or falls below the point of saturation of such air. This elevation, which may be said to constitute *the region of clouds*, must of course be highest under the equator, an inference supported by fact; for it has been observed that within the tropics the clouds are most frequently higher than in the temperate zones, and in the temperate zones the clouds appear to be higher in Summer than in Winter. In the temperate zones, Gay Lussac thinks that clouds, in general, are upheld at an average distance from the earth's surface of between 1500 and 2000 yards. Occasionally, however, clouds have a much greater altitude, and cirri have been seen far above the greatest elevation hitherto attained by man."

In mountainous countries the height of the clouds may be ascertained by direct observation, since they are seen to strike against the sides, to graze the top, or their elevation may be seen by a spectator from the summit of the hill.

In some parts of the world clouds are rarely seen, while in others the sky is seldom clear. These extremes are only characteristic of extreme climates, or depend on local causes. The irregularity of the atmospheric currents occasions the endless variety of sunshine and cloud, which distinguishes the skies of temperate regions and of our own island in particular, where our comfort is so immediately connected with, and dependent on, these atmospheric changes.

It may be useful here to point out the important uses of clouds in the economy of nature; it is by their means as the immediate source of rain, that the waters, so essential to vegetable and animal existence, are carried from the ocean, their great reservoir, over the land, which would not obtain the supply by any other means, owing to its general elevation above the level of the sea. They also serve to temper the heat and preserve vegetation from the fatal effects of uninterrupted sunshine by day, and act as a covering to prevent the escape of the warmth from the earth by radiation during the night.

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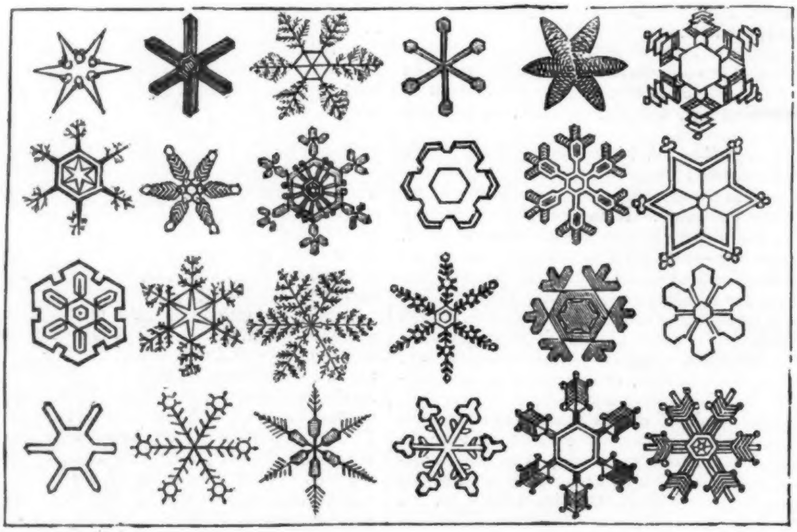
In a subsequent Supplement we shall describe the phenomena of Rain, Snow, &c. Our readers will find the preliminary observations of the present number necessary to the correct conception of all atmospheric changes, and they are exhorted to study the subject well, if they wish or hope to acquire any rational degree of knowledge of the subject.



FORMS OF CRYSTALS OF HOAR-FROST AND SNOW.

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